SLOVENSKI STANDARD
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Laserji in z laserji povezana oprema - Preskusne metode za ugotavljanje praga poškodbe, povzročene z laserjem - 1. del: Definicije in splošna načela (ISO/DIS 21254-1:2024)

Lasers and laser-related equipment - Test methods for laser-induced damage threshold - Part 1: Definitions and general principles (ISO/DIS 21254-1:2024)

Laser und Laseranlagen - Prüfverfahren für die laserinduzierte Zerstörschwelle - Teil 1: Begriffe und allgemeine Grundsätze (ISO/DIS 21254-1:2024)

Lasers et équipements associés aux lasers - Méthodes d'essai du seuil d'endommagement provoqué par laser - Partie 1: Définitions et principes de base (ISO/DIS 21254-1:2024)

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Lasers and laser-related equipment — Test methods for laser-induced damage threshold —

Part 1: Definitions and general principles

Lasers et équipements associés aux lasers — Méthodes d'essai du seuil d'endommagement provoqué par laser —

Partie 1: Définitions et principes de base

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 172, *Optics and Photonics*, Subcommittee SC 9, *Laser and electro-optical systems*.

This second edition cancels and replaces the first edition (ISO 21254:2011), which has been technically revised.

The main changes compared to the previous edition are as follows:

— Functional damage criteria and functional damage threshold (F-LIDT) are introduced;

— New units of laser irradiation level are introduced;

— Two new test protocols are introduced:

  — Extension to R(S)-on-1 test;

  — Extension to the raster scan test;

— Integration of a new section “General Usage Notes” in Annex A;

— Discussion on accuracy of measurement units is extended.

A list of all parts in the ISO 21254 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html

Introduction

Optical components are irreversibly damaged above the so-called Laser-Induced Damage Threshold (otherwise referred to as LIDT or damage threshold): which is the maximum laser irradiation level at which it is expected that there is zero probability of damage. Below the single-shot damage threshold, a delayed damage event might also develop over time as a consequence of repetitive laser irradiation, the so-called fatigue effect. Alternatively, repeated exposure with gradually increasing laser irradiation can cause an increase in the damage threshold; the so-called conditioning effect. For the vast majority of use cases, the damage tends to develop on optical surfaces. Only on specific occasions will it occur within the bulk. Thus, if not requested or declared otherwise, the laser-induced damage threshold is tested and reported for the entrance surface of the optical component. For optics with high transmittance, damage may first develop at the exit surface or in the bulk without observing a damage of the entrance surface due to radiation field enhancement effects: self-focusing, diffraction or interference with back-reflected light. Back surface damage might also feature lower damage thresholds than the entrance surface as a consequence of poor optical quality. In such cases a functional damage threshold testing can be conducted for the exit surface. However, focusing conditions and the functional damage criterion need to be documented in the test report. Environmental contamination by airborne particles, volatile organic compounds, vacuum exposure, and technological imperfections such as nodular defects of coatings, polishing scratches, Beilby layer, sub-surface damage as well as bulk inclusions, dislocations, or inhomogeneities of any other type are also known to affect the performance of an optical component.

Due to a variety of possible failure mechanisms[7-63], the experimentally estimated “damage threshold” is an aggregated feature of optics handling, environmental conditions, material and surface preparation techniques as well as laser-related exposure parameters such as wavelength, spot size, repetition rate, and pulse duration. As a consequence, there is no single procedure, that could universally satisfy all the testing needs of all the types of optical components available. Instead, different damage testing strategies evolved to address particular needs for testing. Various parts of this document are concerned with the determination of irreversible damage of the optical surfaces and the bulk of an optical component under the influence of laser exposure. This document is dedicated to the fundamentals and general principles of the measurement of laser-induced damage thresholds. Based on the apparatus outlined in ISO 21254-1, measurement protocols for damage testing (1-on-1, S-on-1, R(S)-on-1, and Raster scan) are described in ISO 21254-2, and acceptance testing is described in ISO 21254-3. Recommendations and associated risks pertinent to distinct test procedures will be discussed in more detail in Annex A.

The “classical” 1-on-1 test is a damage threshold measurement procedure that uses one pulse of laser irradiation on each unexposed test site of the specimen. In contrast, the “classical” S-on-1 measurement program is based on a series of pulses with a constant laser irradiation level applied to each unexposed site of the specimen. Testing with multiple laser pulses is closer to the operational conditions in the field, however, the experimental effort necessary for S-on-1 tests is also significantly higher. The ISO 21254-series also introduce new alternatives – concept of “functional” damage threshold and new testing protocols such as R(S)-on-1 and Raster scan. In an R(S)-on-1 test, the same test site is irradiated with sequences of (S) pulses while gradually increasing the irradiation level between particular irradiations until the damage is observed. As a further extension of this measurement concept, the Raster scan technique is designed to irradiate a significant fraction of the test sample area with spatially overlapping laser pulses. ISO 21254-3 describes the acceptance testing for a certain laser irradiation level of optical surfaces, leaving samples that pass the test undamaged. ISO/TR 21254-4, which considers damage detection methods and the inspection of tested surfaces, is a Technical Report which complements this document.

Lasers and laser-related equipment — Test methods for laser-induced damage threshold —

Part 1: Definitions and general principles

WARNING — Laser exposure of toxic materials (e.g. ZnSe, GaAs, CdTe, ThF_4, chalcogenides, Be, Cr, Ni) can lead to serious health hazards.

WARNING — Laser damage threshold testing involves high power lasers, the use of which may come with significant risks, which may include, but are not limited to; eye injury to people; laser burns to people or equipment; ignition of materials; generating debris of toxic materials in the substrate or coating; electrical hazards. It is the responsibility of the user to comply with local guidelines and regulations for their particular set-up.

1 Scope

This document defines terms used in conjunction with, and the general principles of, test methods for determining the laser-induced damage threshold and for the assurance of optical laser components subjected to laser radiation.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes the requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 11145, *Optics and photonics — Lasers and laser-related equipment — Vocabulary and symbols*

ISO 11146-1, *Lasers and laser-related equipment — Test methods for laser beam widths, divergence angles and beam propagation ratios — Part 1: Stigmatic and simple astigmatic beams*

ISO 11146-2, *Lasers and laser-related equipment — Test methods for laser beam widths, divergence angles and beam propagation ratios — Part 2: General astigmatic beams*

ISO 13694, *Optics and photonics — Lasers and laser-related equipment — Test methods for laser beam power (energy) density distribution*

ISO 21254-2, *Lasers and laser-related equipment — Test methods for laser-induced damage threshold — Part 2: Threshold determination*

ISO 21254-3, *Lasers and laser-related equipment — Test methods for laser-induced damage threshold — Part 3: Assurance of laser power (energy) handling capabilities*

ISO/TR 21254-4, *Lasers and laser-related equipment — Test methods for laser-induced damage threshold — Part 4: Inspection, detection and measurement*

3 Terms and definitions

For this document, the terms and definitions given in ISO 11145, and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Symbols and units of measurement

The symbols and units of measurement used are the following:

Symbol	Unit	Term
λ	nm	wavelength
α	rad	angle of incidence (AOI)
p		type and degree of polarisation: linear (s or p), circular, elliptical, random
d_T	cm	beam diameter (peak/e^2 level - for Gaussian beams only) at normal incidence
$d_{T,eff}$	cm	effective beam diameter in the target plane at normal incidence
$A_{T,eff}$	cm^2	effective area of typical laser pulse in the target plane at normal incidence
$\bar{A}_{T,eff}$	cm^2	time-averaged effective area in the target plane corresponding to laser burst at normal incidence
$\bar{E}_{max}$	bit counts	time- averaged numerical value of most intense pixel within the beam profile taken by light-sensitive array for continuous wave (CW) or burst of quasi continuous wave (q-CW) laser irradiation in the target plane at normal incidence
$A_{90\,\%}$	cm^2	AOI-adjusted total irradiated area per test at the highest undamaged irradiation level, below the lowest observed damage or the level set for acceptance testing
τ_{FWHM}	s	pulse duration at full width of half maximum (FWHM)
τ_{eff}	s	effective pulse duration
f_p	Hz	pulse repetition rate
Q	J	pulse radiant energy
P_{pk}	W	peak radiant power
P_{av}	W	average radiant power
H	J/cm^2	peak fluence, AOI-adjusted
H_{max}	bit counts	numerical value of most intense pixel within the single pulse beam profile distribution taken for pulsed laser irradiation in the target plane at normal incidence
E	W/cm^2	average peak irradiance, AOI-adjusted
F	W/cm	peak linear power density, AOI-adjusted
I	W/cm^2	peak irradiance, AOI-adjusted
H_{th}	J/cm^2	threshold fluence, AOI-adjusted
E_{th}	W/cm^2	threshold average irradiance, AOI-adjusted
E_{max}	bit counts	most intense pixel within the beam profile taken by light-sensitive array for for single typical pulse of CW laser irradiation in the target plane at normal incidence
F_{th}	W/cm	threshold linear power density, AOI-adjusted
I_{th}	W/cm^2	threshold irradiance, AOI-adjusted
N_{min}		minimum number of laser pulses required to cause damage
TTF	s	time to failure - minimum exposure time required to cause damage
S	pulse count (or time count)	the maximum number of pulses (or exposure time) per laser irradiation level site
N_{ts}	site count (or cm^2)	total number of sites (or area) for the test

3.2 Terms and definitions

3.2.1
peak fluence
H
AOI adjusted radiant energy per effective area of the typical pulse

$$H = \frac{Q\cos(\alpha)}{A_{\mathrm{T,eff}}} \quad (1)$$

3.2.2
peak irradiance
I
AOI adjusted radiant energy per effective pulse duration per effective area of the typical pulse

$$I = \frac{H}{\tau_{\mathrm{eff}}} = \frac{Q\cos(\alpha)}{A_{\mathrm{T,eff}}\tau_{\mathrm{eff}}} \quad (2)$$

3.2.3
peak linear power density
F
AOI adjusted average power of laser irradiation per effective beam diameter

$$F = \frac{P_{\mathrm{av}}\cos(\alpha)}{d_{\mathrm{T,eff}}} \quad (3)$$

Note 1 to entry: The cosine of the angle of incidence addresses the elongation of effective beam in the projected target plane.

3.2.4
average peak irradiance
E
AOI adjusted average radiant laser power per time-averaged effective area:

$$E = \frac{P_{\mathrm{av}}\cos(\alpha)}{\bar{A}_{\mathrm{T,eff}}} \quad (4)$$

3.2.5.1
effective area
$\boldsymbol{A_{\mathrm{T,eff}}}$
<pulsed lasers> ratio of total pulse energy to peak fluence in the target plane at normal incidence:

$$A_{\mathrm{T,eff}} = \frac{Q}{H} \quad (5)$$

3.2.5.2
effective area
$\boldsymbol{\bar{A}_{\mathrm{T,eff}}}$
<CW-laser or quasi-CW laser systems> ratio of the average power P_{av} and the time-averaged peak irradiance E at normal incidence

$$\bar{A}_{\mathrm{T,eff}} = \frac{P_{av}}{E} \quad (6)$$

Note 1 to entry: The subscript T indicates the target plane (see 5.3.5) as a reference at normal incidence.